The X-Ray Derived Cosmological Star Formation History in the Chandra Deep Fields North and South

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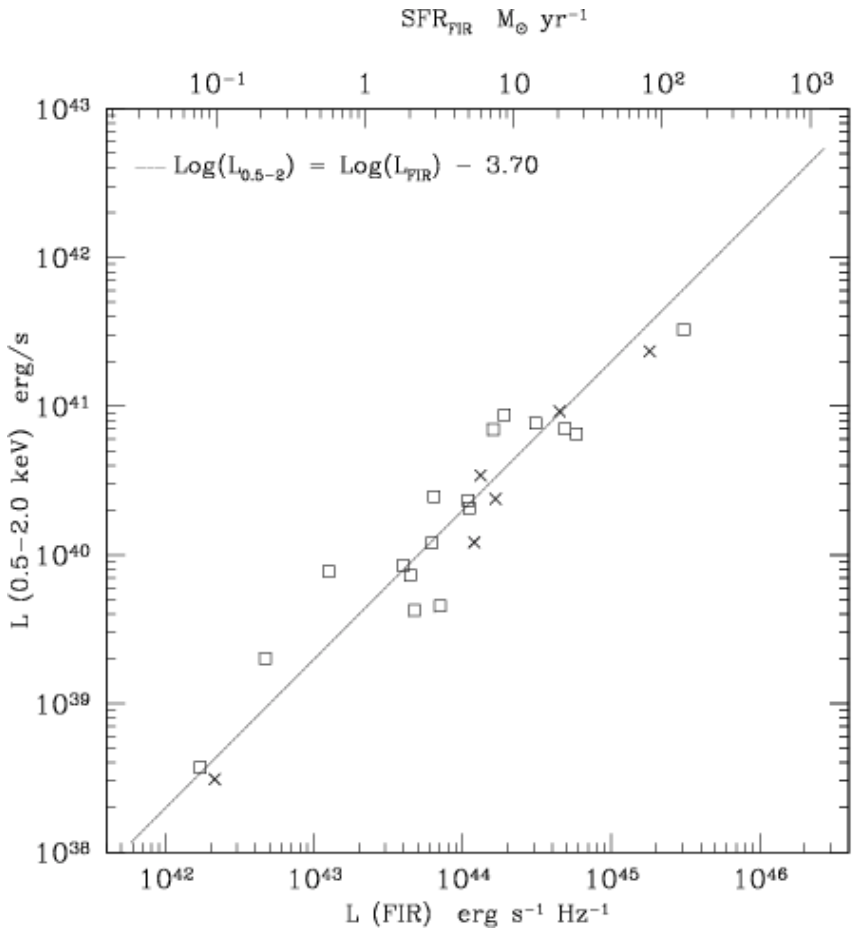
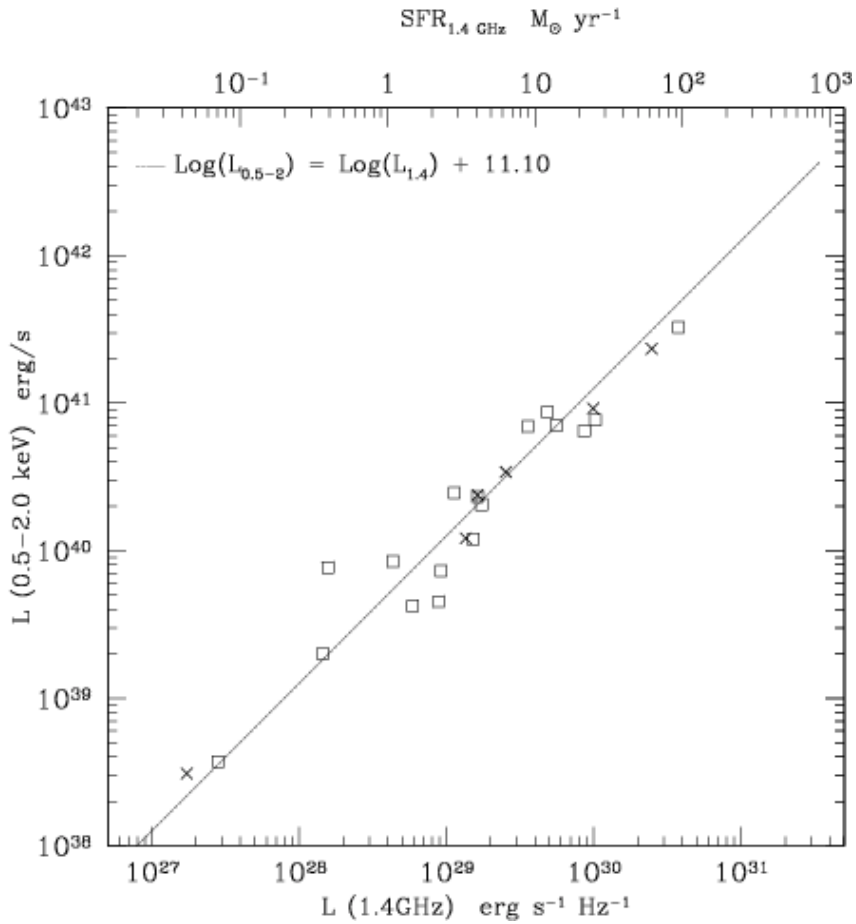
Background

- X-rays have been known to correlate with FIR since Einstein era (Fabbiano 1989; Griffiths & Padovani 1990; David, Jones & Forman 1992; Green, Anderson & Ward 1992).
- Natural explanation: X-rays are produced by massive stars, SN, SN-heated ISM, HMXRB that all track star-formation rate (SFR).
- Can X-rays be used as an effective cosmic SFR measure?

X-ray vs. FIR and Radio

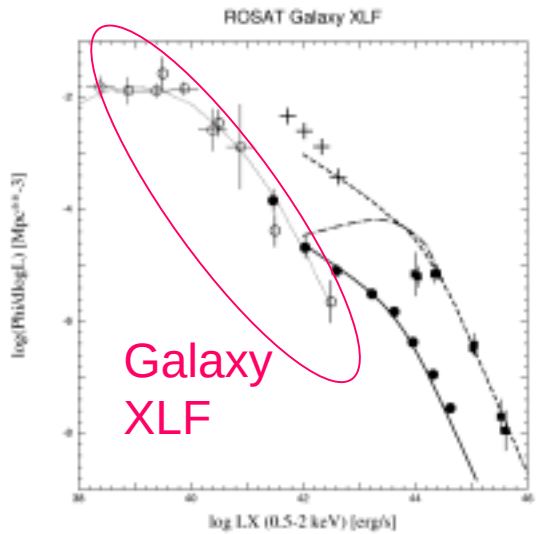




From Ranalli et al. (2003)

Galaxy Luminosity Functions

- X-ray luminosity function (XLF) for “normal” star-forming galaxies should exhibit evolution consistent with SFR evolution.
- Galaxy XLF only measured to date for z = 0 (Hasinger 1998) using ROSAT (also indirectly in Georgantopoulos et al. 1999).



Galaxies in CDF North and South

- Chandra Deep Fields North and South have been observed for 2 and 1 Ms (limiting fluxes of ~ 3 x 10^{-17} ergs cm^{-2} s^{-1} and 6 x 10^{-17} ergs cm^{-2} s^{-1}).
- ~ 47 (CDF-S) and 62 (CDF-N) galaxies identified via optical spectra
  - More detailed analysis of CDF-S optical spectra resulted in a “conservative” sample with 29 galaxies

Bayesian Statistical Analysis

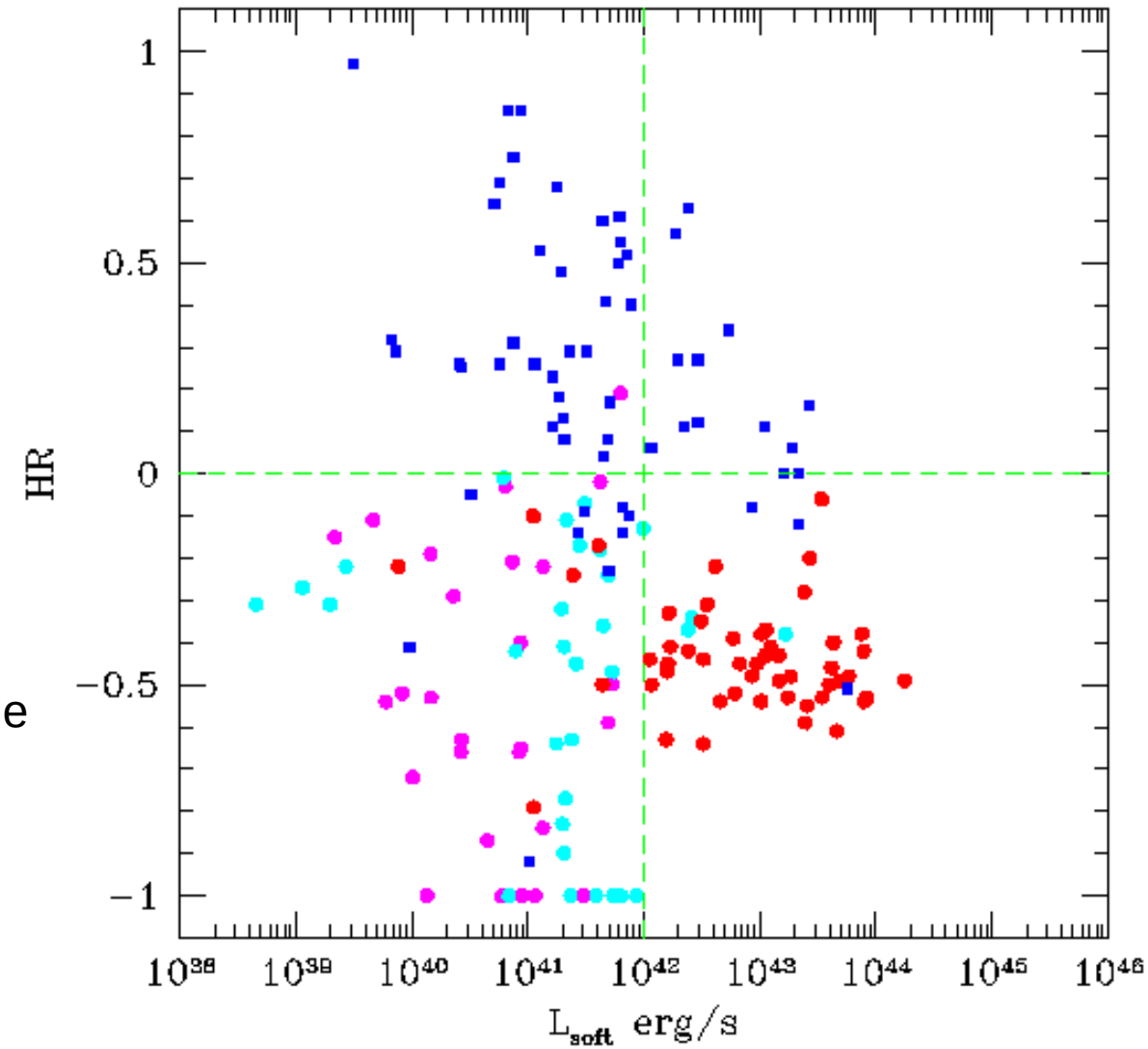
- Also selected galaxy candidates based on a Bayesian model
- Computed mean and standard deviation of various parameters: L_X, hardness (HR), L_{Radio}, R, K
- Best separation between galaxies, AGN1 and AGN2 was with L_X and HR.
- Prob. of observed source parameters (including errors) being consistent with a model:
  - $P(L, HR) = \int dL' \int dHR' \, P_M(L', HR') \, L(L \mid L') \, L(HR \mid HR')$
  - $P_M(L', HR')$ = "prior" = model parent probability distr.
  - $L(HR \mid HR')$ = likelihood function for observing HR

L_X vs. HR

Blue = AGN2
Red= AGN1
Purple = Galaxies
Cyan = Photometric sample

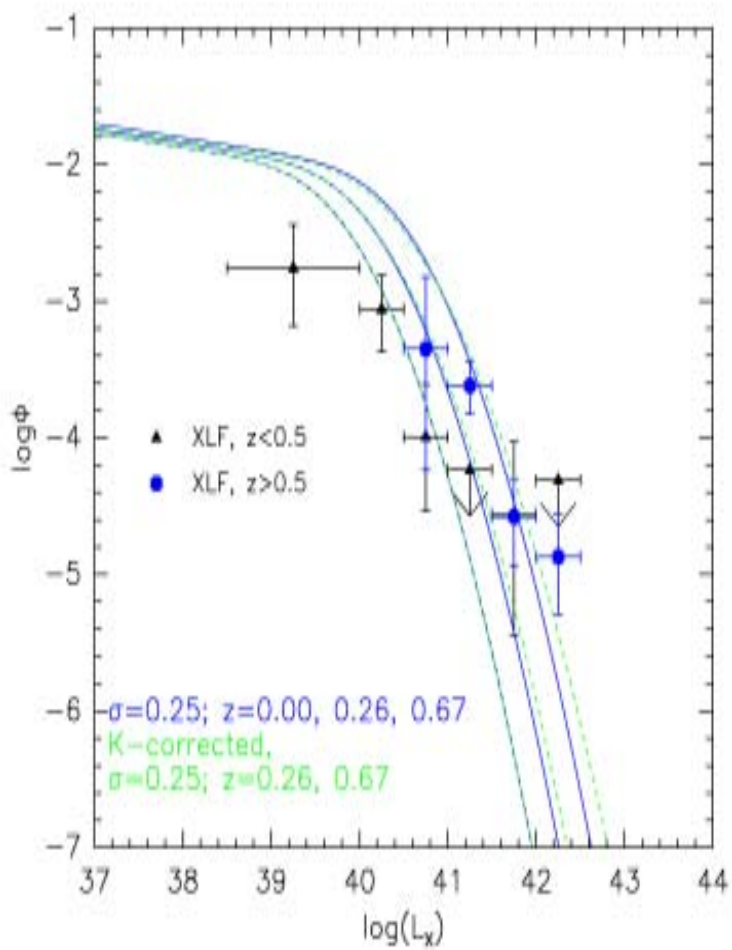
N.B. Spectroscopic IDs include low-quality spectra

Typical error in HR often >0.5



Z>0 Galaxy XLF

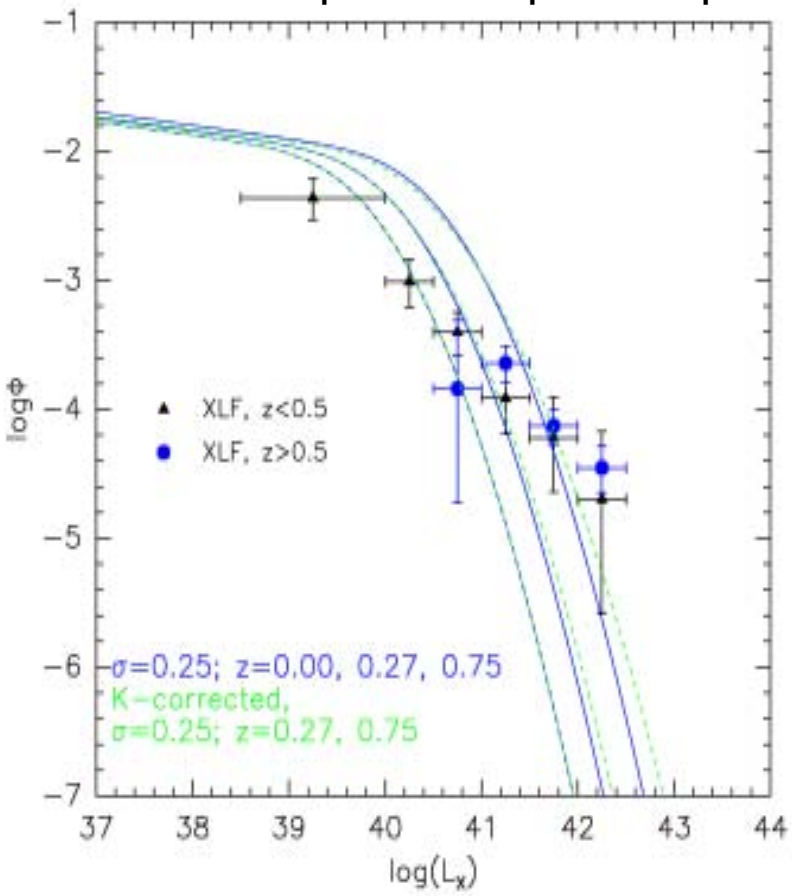
- Converted FIR LF to X-ray using Ranalli et al. (2003) log $F_{0.5\text{-}2.0\ keV}$ / log FIR correlation and assuming a dispersion of 0.25.
- Also included effects of X-ray k-correction (minor since starburst X-ray SED is relatively flat) and $(1+z)^{2.7}$ luminosity evolution.



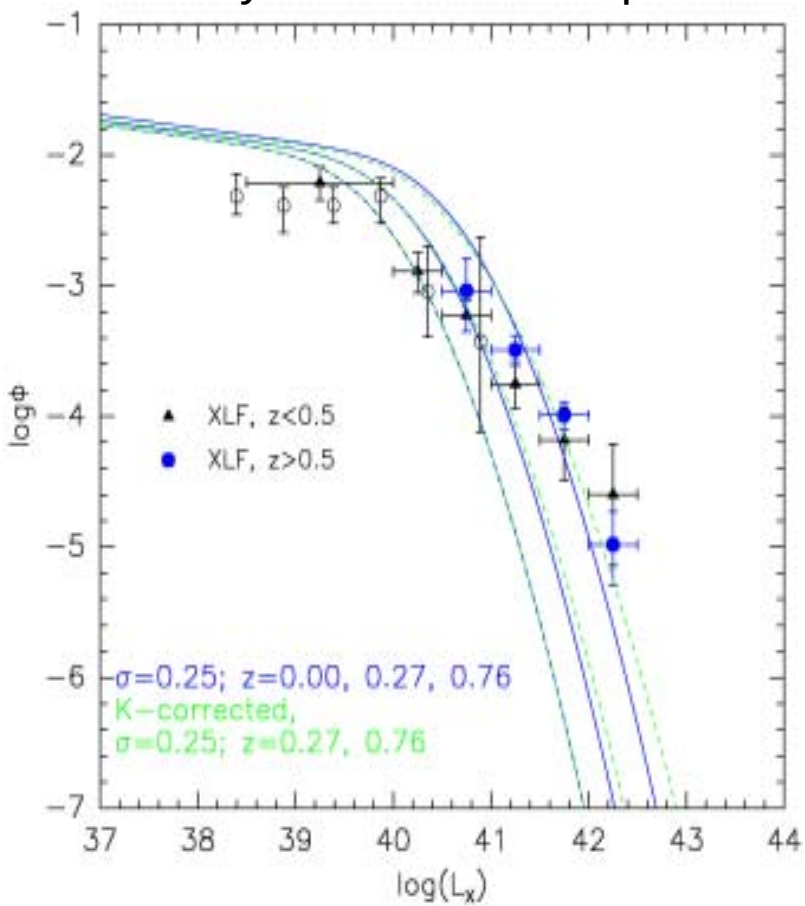
"Conservative" CDF-S

Z>0 CDF-N + CDF-S XLFs

"Liberal" Spectroscopic Sample



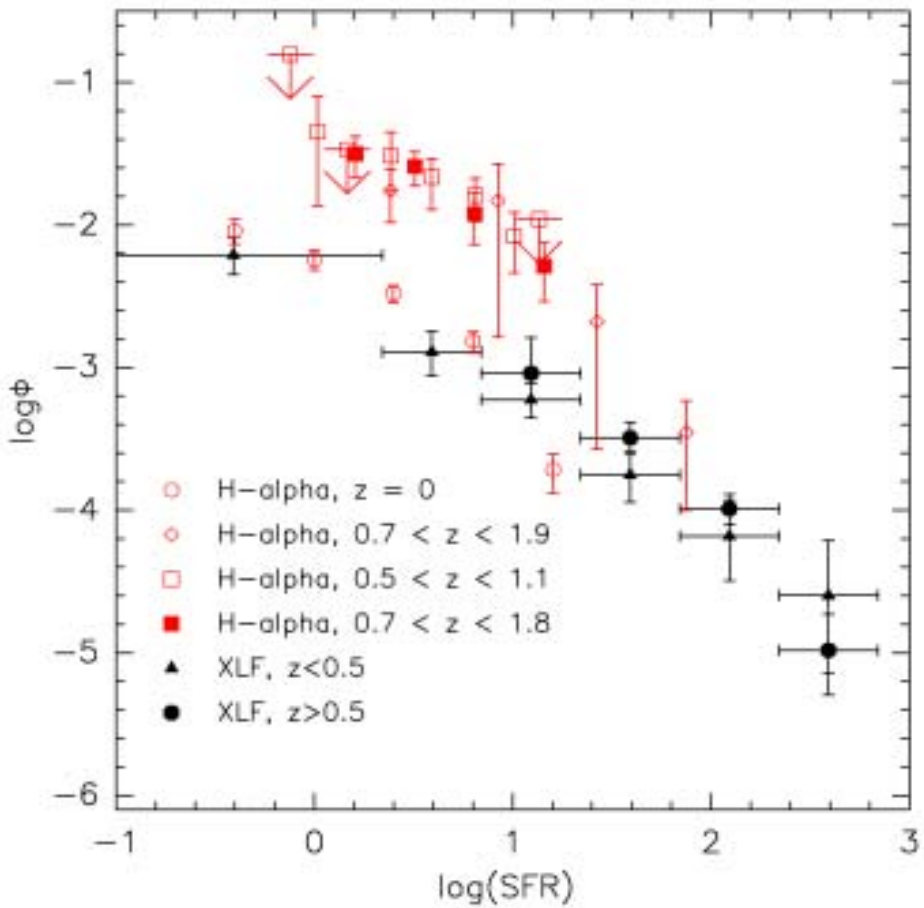
Bayes-selected Sample



Z=0 XLF from Schmidt, Boller, Voges (1996), adjusted by factor of 3 for local over-density

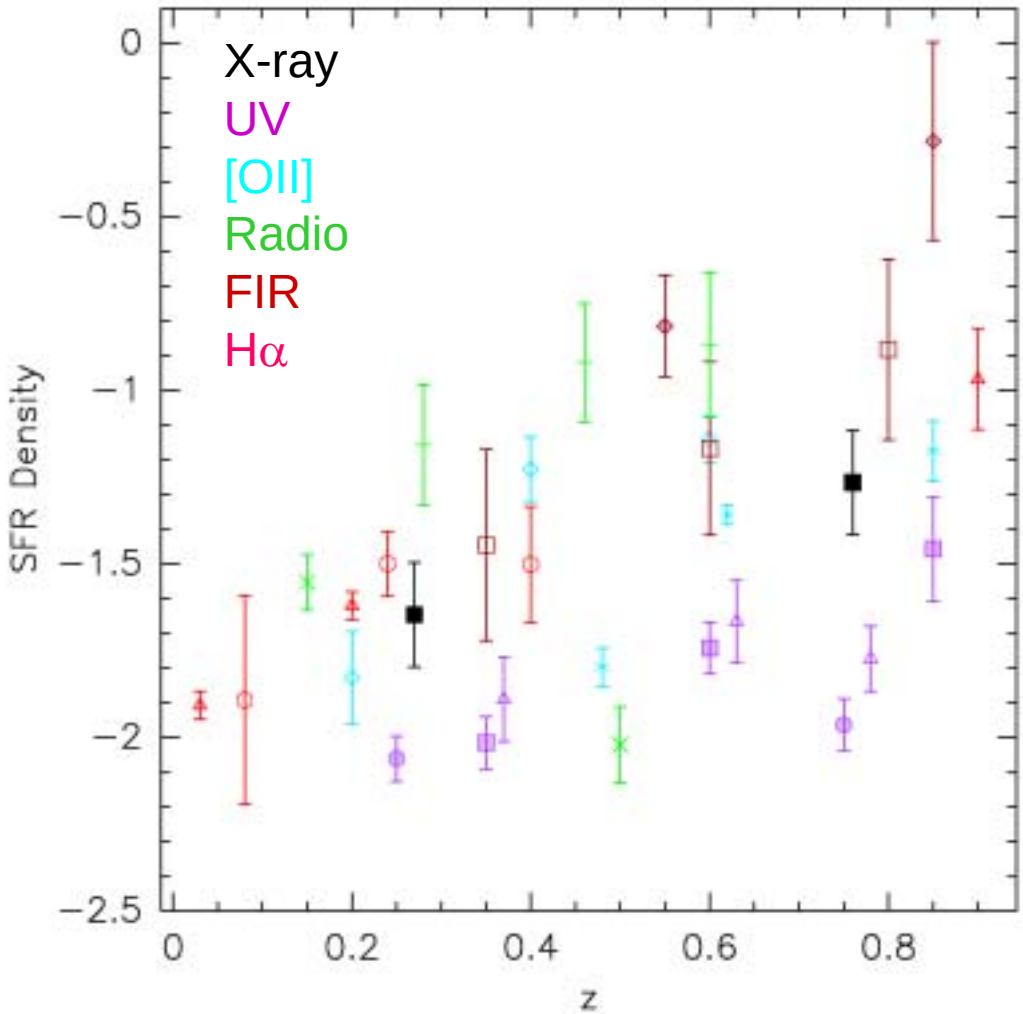
Hα Comparison

- Hα and X-ray (CDF-S + CDF-N Bayes sample) converted to SFR in order to compare luminosity functions
- z<0.5 XLF consistent with z=0 Hα LF, z>0.5 X-ray LF consistent with extrapolation of z ~ 1 Hα LF



X-ray SFR History

- SFR data courtesy of David Hogg
- X-ray points computed from average of direct integration of XLF and integration of z=0.25 and z=0.75 FIR models



Conclusions

- X-ray spectroscopic sample suffers from incompleteness at low luminosities, AGN contamination at high luminosities.
- X-ray Bayesian sample shows more agreement with FIR LF, particularly for $z>0.5$. AGN contamination is still a problem, particularly for $z<0.5$.
- SFR predicted from X-ray LF consistent with general trends from other band passes (see also Georgakakis et al. 2003).
- Factor of ~ 2 evolution due to LMXRB is also expected at $z \sim 0.5$ (Ghosh & White 2001; Ptak et al. 2001) and may be contributing (but evolution not observed in L_X/L_B) .
- Future work will concentrate on improving Bayesian galaxy classification model to many dimensions, including, e.g., GOODS data
- X-rays promise to be good SFR measure relatively unaffected by extinction issues for Chandra deep surveys and future wide-area X-ray missions.